RESEARCH HIGHLIGHT

March 2007 Technical Series 07-109

Testing Oil-fired Appliance Depressurization Spillage

INTRODUCTION

It has been impossible to find oil-fired equipment designed to work in houses with negative pressures. House depressurization can cause combustion, which creates objectionable odours and may have health implications. This *Research Highlight* relates how one manufacturer of oil appliances investigated solutions for spillage and odours.

Spillage from combustion appliances in Canadian homes is a complex problem. The frequency and severity of combustion spillage is affected by the airtightness level of the house, the way the equipment is installed and the use of other air-exhausting equipment in the home. Other air-exhausting equipment can overpower the appliance venting system and cause combustion spillage.

Existing Canadian codes and standards have attempted to deal with combustion spillage by such strategies as requiring makeup air supplies for installations that may not have sufficient air leakage to support the proper operation of the combustion appliances.

Manufacturers have also developed appliances that are more spillage-resistant. However, there is no standard protocol to directly test and rate products for resistance to combustion spillage. Manufacturers have not had an accepted way to notify consumers, builders or other stakeholders of the rated spillage resistance of their appliances, or to indicate which of their products perform better under reduced pressure conditions that might cause spillage in other products.

The depressurization-spillage test was developed by Canada Mortgage and Housing Corporation, Natural Resources Canada and other stakeholders as a key instrument in addressing this gap.

The combustion-spillage test uses CO_2 produced in combustion as a tracer gas. The amount of CO_2 spilled into the test room for a particular level of depressurization is measured and totalled over the duration of the test. This is then compared with the amount of CO_2 produced by combustion during the test to determine the percentage of combustion spillage. *Combustion spillage* is defined as any products that are formed by combustion of a fuel that are released from the appliance or its venting system into the test room.

Kerr Heating Products of Parrsboro, N.S., partnered with CMHC and NRCan to develop its in-house capabilities for evaluating the spillage resistance of oil-fired appliances. During the project, Kerr installed, commissioned and used an in-house depressurization-spillage test facility.

The facility, the test procedure and calculations were similar to those that were used for natural gas appliances in an earlier CMHC project (see *References* at the end of this *Research Highlight*). This project is the first time that any Canadian HVAC (heating, venting and air conditioning) manufacturer has expanded its product development capabilities by building and using in-house depressurization-spillage testing tools. It was also the first time that the test had been used with appliances intended for vertical (chimney) venting. The Kerr team updated the calculations from the earlier gas-fired project to incorporate the correct fuel composition for oil-fired equipment. Kerr evaluated several design alternatives and instrumentation choices for the test room. The full project report explains the decisions and provides full details for the updated test procedure and its associated calculations. Performance measurements for some residential oil-fired combustion appliances are provided at different depressurization levels. Kerr provided a template to enable other appliance manufacturers to readily deploy their own in-house depressurization testing capabilities.

This research project focused on identifying challenges for a manufacturer implementing the spillage test. The manufacturer has to overcome these barriers and take the test from a laboratory setting (where it has already been proven to work) to its own product development environment.

This project also produced test results on the combustion-spillage performance of some oil-fired heating products with a range of different vent configurations and components.

RESEARCH PROGRAM

The research program was conducted between December 2005 and August 2006 at Kerr's product development facility in Truro, N.S.

A second-hand environmental room was purchased and reassembled for this research program. A pressure blower with an adjustable inlet damper was installed to exhaust air from the room and control the test room pressure at the desired level.

Instrumentation was purchased and installed to measure the amount of air removed as well as the concentration of carbon dioxide (CO_2) in the air removed from the test room. The fuel consumption, CO_2 level in the area surrounding the test room, test room temperature and pressure and flue gas measurements in the appliance vent were also taken for each test.

A data acquisition system automatically logged test data and a Microsoft Excel template was developed to perform calculations for each test and account for changes in test-room temperature, barometric pressure and so on during each test and between tests.

For each test, the appliance with its vent system was first installed in the test room. The room was depressurized to the desired level and the appliance controls were adjusted so that the burner operated for five minutes.

The amount of CO_2 that was released or "spilled" into the test room was determined over seven minutes—the five that the burner operated and another two to include spillage of combustion gases from the venting system after the burner shut down. The amount of CO_2 spilled into the test room was divided by the amount of CO_2 produced by the burner to determine the percentage of combustion spillage for each test.

Full details of the procedure and calculations were included in spreadsheet templates. The templates are available on CD.

To simplify interpretation of test results, a tolerance level of allowable spillage was established for the testing. If the amount of spilled CO_2 exceeded two per cent of the CO_2 produced by combustion, the appliance was considered to have failed the depressurization spillage test. The two per cent level corresponds with the project testing gas appliances and the "Gas Passageway Leakage Test" described in Section 21 of CSA B140.0-03, *Oil-Burning Equipment: General Requirements.* Note that B140.0 allows two per cent leakage for both the heat exchanger and the vent sections and that UL726, *Standard for Oil-Fired Boiler Assemblies*, allows four per cent spillage from the combustion chamber—vent section and eight per cent from the air intake section. The two per cent level for this research project is at least twice as stringent since all of the interfaces are not tested in the B140.0 or UL requirements. Further work based on health considerations may be required to establish an "acceptable" combustion spillage level for installed oil-fired equipment.

RESEARCH FINDINGS

Cost of new test equipment

Most appliance manufacturers will already have much of the equipment and skills needed to perform depressurization testing. Kerr required some additional equipment for this research project.

Kerr selected and purchased the new test equipment for this project based on performance, cost and durability considerations. The equipment needed to be accurate enough to ensure that the spillage was properly determined, be easy to operate and have the appropriate ruggedness and reliability for use in an industrial environment.

Table 1 gives the range and accuracy of the instruments selected.

Table 1 Measurement ranges and instrument accuracy specifications

Measured property	Range	Accuracy
CO_2	0–1,000 ppm	±1% full scale
Flow	0–500 cfm	±0.5%
Pressure 1	0–200 Pa	±1% reading
Pressure 2	0–2000 Pa	±1% reading
Temperature	0–200°F	±2°F

Table 2 lists the equipment Kerr purchased for this project.

Table 2 Equipment list and purchase cost

Item	Purpose	Cost
1 test room	To allow depressurization testing	$4,150
1 depressurization fan/motor	To depressurize test room and overcome pressure difference across flow element	$444
1 laminar flow element	To measure flow from test room	$1,800
2 CO_2 meters	To measure CO_2 in test room and adjacent room	$5,000
1 calibration gas	To calibrate CO_2 meters	$270
1 digital manometer	To measure static pressure and pressure difference across the laminar flow element	*
1 digital manometer	To measure depressurization level in test room	*
1 combustion gas CO_2 analyzer	To determine the flow through the burner and barometric for non-direct vent systems	*
1 programmable logic controller	To control test events (optional)	*
1 data acquisition system	To collect data	*
5 thermocouples	To measure temperatures	*
1 computer	To record test parameters and process data	*
1 digital camera	To record test set ups	*
1 scale	To determine weight of fuel used	*
Cost of new equipment		$11,664

* Equipment already available to Kerr – no purchase required

Description of tested appliances

The project tested oil-fired furnaces and hot water boilers. Table 3 is a list of the appliances and their venting configuration. Configurations identified as "Direct Vent" did not use barometric dampers. The systems were tested for combustion spillage at different depressurization levels, nominally 5 Pa, 8 Pa, 20 Pa and 50 Pa.

Table 3 Tested appliances and vent configurations

Product type	Venting configuration
Warm air furnace	Chimney (extended vent) with barometric damper
Warm air furnace	Chimney (extended vent) with no barometric damper
Warm air furnace	Chimney (short vent) with barometric damper
Warm air furnace	Chimney (short vent) with no barometric damper
Warm air furnace	Chimney (extended vent) with barometric damper
Warm air furnace	Chimney (extended vent) with barometric damper
Warm air furnace	Chimney (extended vent) with no barometric damper
Warm air furnace	Chimney (short vent) with barometric damper
Warm air furnace	Chimney (short vent) with no barometric damper
Warm air furnace	Flex vent connected to chimney, combustion air from room
Warm air furnace	Direct vent
Warm air furnace	Direct vent
Warm air furnace	Direct vent with quick disconnect 1
Warm air furnace	Direct vent with quick disconnect 2
Hot water boiler	Direct vent
Hot water boiler	Direct vent with quick disconnect 1
Hot water boiler	Direct vent with different burner flanges

Results

Figure 1 summarizes the results of the spillage tests. See also Table 4.

It is important to note that the main focus of this project was to refine, evaluate and demonstrate the test protocol with oil-fired appliances—not to develop the appliances. However, it is likely that the installation procedures for the later tests were improved from the earlier tests because of what had been learned during the project.

Different appliances and components were used to evaluate the spillage test with a variety of configurations. There was no attempt to undertake comprehensive comparative evaluations of the performance of an appliance operating with the different configurations identified in Table 4 and all configurations were not tested at all depressurization levels.

Except for some fairly simple modifications, no efforts were taken to improve the performance of any of the appliances during this project. This explains why the results show varying spillage for similar configurations.

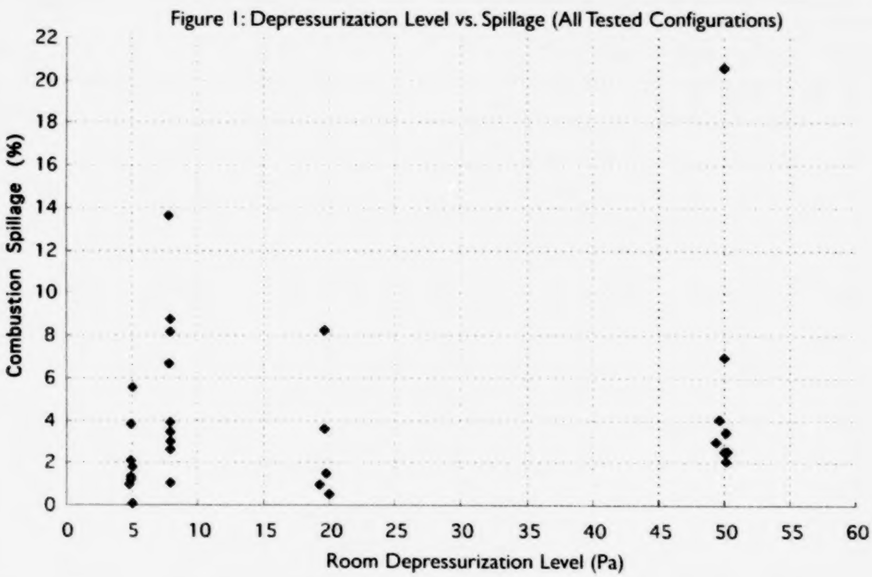

Figure 1 Results of spillage tests

Table 4 Spillage results with different types of venting systems

Type of venting system	Depressurization (Pa)	Amount of spillage (%)
Chimney with barometric	5	1–6
Chimney without barometric	5	1–7
Chimney with barometric	8	3–14
Chimney without barometric	8	1–7
Flex vent connected to chimney Combustion air from room, no barometric	8	1
Flex vent connected to chimney Combustion air from room, no barometric	20	8
Flex vent connected to chimney Combustion air from room, no barometric	50	21
Direct vent	50	1–7

CONCLUSIONS

Easy-to-use test—a useful tool for product development

A key conclusion from this project is that a low-cost test is now available that allows manufacturers of oil-fired appliances to directly determine the effects of depressurization on their equipment.

This test has proven very useful in evaluating different design alternatives for effectiveness when subjected to a depressurized environment. The spillage test can be easily and inexpensively implemented by other manufacturers.

Kerr has decided that this capability is an important tool for the development of future oil-fired systems. It has already incorporated the new tool in their other projects, including ones to evaluate different burner flange designs, quick-release vent couplings and a reversible breech, low-boy furnace.

Sensitivity and repeatability

The sensitivity of the test is such that subtle differences cited in the above examples could be determined. Repeatability is good and well within the requirements of a test of this type. The test is very quick to perform once the appliance is set up. Warm air furnaces require a brief cool-down between tests, which can be reduced by turning the exhaust fan to high speed.

Some systems can withstand significant depressurization

Figure 1 shows that there are systems that pass the two per cent spillage test, even when operated up to 50 Pa depressurization. While there was a wide range of spillage results for the tested configurations, the two per cent spillage limit is obtainable with good appliance and venting system design and good installation practices.

Effect of different venting systems

Chimney-vented appliances that used barometric dampers did not perform well above 5 Pa depressurization. This finding was expected, but it is important to note the appliance has little impact on the spillage since most occurs in the vent and through the barometric damper. Careful attention to sealing the smoke pipe helps. Traditional smoke pipe does not perform well in a depressurized environment unless the joints are sealed with aluminum tape.

A hybrid vent system taking combustion air from the room but venting into a sealed exhaust with no barometric damper offers much higher resistance to depressurization spillage than a conventional chimney vent. This venting approach appears to offer some promise for future products.

Current oil-fired direct vent technologies, such as sealed-combustion direct venting, can meet a spillage requirement of two per cent or less at 50 Pa depressurization when properly designed and installed.

However, direct venting has some problems related to venting out the sidewall. There appears to be good potential for developing and demonstrating an upgraded type of combustion venting system that would draw its combustion air from outside the house envelope while venting vertically, without using a barometric damper. This approach would have the advantages of current direct-vent systems without the problems related to sidewall venting.

Effect of different burner designs

Although only four different burners were tested there are clearly differences among burner designs with respect to depressurization spillage. The approach to sealing the burner flange to the boiler or furnace also had an impact on spillage. This information can be used by burner manufacturers to improve their depressurization performance. Two major oil burner manufacturers have already expressed interest in this work and it is anticipated that burner depressurization performance will be improved in the future.

Value to manufacturers

Kerr originally considered building a test facility that could be dismantled when not in use. Kerr has found the facility to be extremely useful during the product development cycle, and now uses it regularly. Knowledge from depressurization testing has already been used to upgrade installation practices and manuals.

Value to industry

Given that the incidence of depressurizing homes is increasing and recognizing that spillage of combustion products from oil-fired appliances creates both sooting and odour, there is a significant opportunity for stakeholders within the industry to develop their own testing capability and to use that capability to reduce depressurization-related performance issues.

REFERENCES

Laboratory depressurization test for residential gas appliances, CMHC Research Highlight—Technical Series 05-111, October 2005.

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Laboratory evaluation to assess a proposed test method to determine transient combustion spillage, prepared by Bodycote Materials Testing Canada Inc. for NRCan, July 2005.

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Funding Partner: Natural Resources Canada (NRCan)

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